Preliminary economic assessment of water resources of the Pangani River Basin, Tanzania: economic values and incentives

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Abstract

A study was conducted in Pangani River Basin to provide estimates of the value of water in different uses, and review various issues and economic tools pertaining to water resource allocation and financing mechanisms in the basin. The study was carried out in October-November 2003. Literature, GIS data, interviews, focus group discussions and a household survey were conducted.

Preliminary findings on the value of water in alternative uses indicated that for irrigated agriculture such as coffee, the estimated average value was about Tsh 700 – 6000/m³. Roughly Tsh. 30 – 100/m³ for large scale sugar production, Tsh 3500 – 5300/m³, for greenhouse-based cut-flower industry, Tsh.200 – 600/m³ for small scale traditional irrigation furrows, while for improved furrows the average value ranged from Tsh. 600 – 1400/m³. Water prices for domestic consumption were equivalent to Tsh 1500 and 1250 in per m³ in the highlands and lowlands respectively.

Some National and sectoral policies promote natural resource exploitation while others promote sustainable practices that enhance water supply. There is enormous potential to increase the revenues in the basin from user fees.

Keywords: *economic valuation of water, Pangani River Basin*

As water resources become increasingly scarce in Africa, the need for the use of economics to aid in decision-making and management becomes apparent. Indeed, global experience shows that economic approaches may achieve the best results. Water is the basis of the economy as well as essential for human life and biodiversity. The Pangani River Basin in north-eastern Tanzania provides a good starting point for evaluating the economic issues around water resources and how economics can be used to improve their management to align with national goals.

Tanzania has committed itself to an ambitious poverty reduction strategy, and plans to transform itself into a middle-income country by 2025. This will require massive economic development and growth. Yet Tanzania faces water scarcity in some cases, at least partly due to the inefficiency with which water is allocated and used. This scarcity has been exacerbated by population and economic growth, which has not been accompanied by improved resource management. Fortunately Tanzania has adopted a progressive National Water Policy that aims at sustainable development and management of water resources. A Water Resources Strategy and Legislation are being drafted. For the first time, water allocation will consider both human needs and environmental protection. In addition, the policy aims to implement fees for financing water resources management and to use economic and other instruments to manage the use of water resources and ensure long term sustainability.

The principal concerns affecting water resource management in the Pangani basin are:

Threats to water supply – due to climate change, forest degradation, inefficient uses and pollution;

Increasing demand for water – due to population and economic growth;

Shortages for power generation – due to upstream water abstraction and siltation of dams;

Conflicts over water resources – between different sectors and between upstream and downstream users;

Environmental degradation – due to reduction in water flows necessary to sustain ecological processes and sustainable livelihood practices;

Insufficient funds for water resources management – inadequate government funding exacerbated by lack of income from users;

Cultural heterogeneity – the diversity of users and their relationships with the environment creates challenges for water management.

The Pangani River basin and it's management

The Pangani River drains a basin of 43,000 km2 in north-eastern Tanzania and a small part of Kenya. The basin contains fourteen districts and two municipalities, falling within the Kilimanjaro, Manyara, Arusha and Tanga Regions of Tanzania. Mount Kilimanjaro and Mount Meru provide the main source of river flow, and the basin also drains the Pare and Usambara Mountains in the north-east. Numerous tributaries drain the mesic highland and upper basin areas, whereas water is far more scarce in the arid lowland areas, with the Pangani River being a prominent feature in the landscape.

In addition to several small natural lakes, a dominant feature is the 14,000 ha Nyumba ya Mungu Dam located on the Pangani River in the upper basin. Several wetlands exist in the basin, most notably the Kirua swamps downstream of Nyumba ya Mungu which covers 90,000 ha.

The highland and upper basin areas are characterised by urbanisation, densely populated rural areas and cultivation. The lowlands have scattered croplands associated with smaller settlements, usually close to the Pangani River. Arid rangelands make up much of the remaining landscape. The total population of Pangani River Basin is approximately 2.6 million. Population growth rates are up to 4.0% in the highland areas (Arusha Region) but relatively low towards the coast (1.8% in Tanga Region).

While water supply depends primarily on precipitation in the highland areas, it is greatly affected by management of the whole catchment, particularly in the highlands. Natural forest cover encourages infiltration of water during the rainy season, which is then released gradually, maintaining flows throughout the year. As forest and other vegetation and soil cover is degraded, so less water infiltrates and more water is lost during flood periods. The quality of water supply is also affected by catchment activities which lead to soil erosion and pollution.

Water resources of the Pangani River Basin plus three much smaller basins (total 56 000 km2) are managed by the Pangani Basin Water Office, which allocates user rights for water. Most water allocated is to the higher lying areas. The natural environment has not been considered as a consumer of water and has therefore not received direct water allocations. Indeed changes in the management of Nyumba ya Mungu Dam since 1994 have led to reduced downstream flows and the consequent drying up of a large proportion of the Kirua Swamp. Environmental resources have been effected as far as Pangani estuary, where saltwater intrusion is a problem, and the associated near-shore environment, where some farming and fisheries are thought to have declined as a result of decreased freshwater flows.

The Value of Water Consumption

Domestic Consumption

Domestic consumption of water could be argued to be the most important type of water use in the basin, in that it is vital to human wellbeing. Tap water is supplied to major urban areas, smaller towns and a large number of rural villages. However, a large proportion of the population relies on fetching their own water from rivers and wells (rural population of Pangani River Basin = 2.16 million, urban population = 427,000). Urban consumption is estimated to be in the region of 70 litres per person per day, while rural consumption is about 37, 22, 18 and 28 litres per person per day in the highlands, upper basin, lowlands and coastal areas respectively.

The value of water for domestic use is probably better reflected by the willingness to pay, demonstrated through trade of water in rural areas, than by prices set by authorities in the urban areas. Water prices are equivalent to Tsh 1,500, Tsh 1,250 and Tsh 1,200 per m3 in the highlands, lowlands and at the coast respectively, far higher than the prices charged by PBWO. Total willingness to pay for, or value of, domestic water supplies in Pangani River Basin is estimated to be in the order of Tsh 37 – 46 billion.

Irrigated Agriculture

Agriculture is the biggest user of water with over 50,000 ha of fields irrigated in Pangani Basin. This includes large commercial estates (mainly coffee, also sugar), flower farming and small-scale mixed cropping. Small-scale farmers have plots of about 0.1 – 0.2 ha in the highlands, increasing to 0.8-1.5 ha in the lowlands.

Coffee is Tanzania's largest export crop, and is produced on large estates and by small-holders. Production is strongly correlated with rainfall and irrigation inputs. Large scale coffee production in the study area consumes an estimated 1,000 m3 per ha per year (excluding processing), generating an average income of about Tsh 700 – 6,000 per m3 of water consumed. Sugar production is mostly large-scale, but it is also grown by small-scale farmers. About 85% is sold locally, the remainder being exported. Sugar consumes about 12 – 17,000 m3 per ha per year (excluding processing), with an average value of roughly Tsh 30 – 100/m3 water. The greenhouse-based cut-flower industry covers a total of 80 ha, and is mostly for export. Water consumption is estimated to be about 18,250 m3 per ha per year, but average value is estimated to be as high as Tsh 3,500 – 5,300/m3 (See Table 1 below).

Small-scale farmers make use of an estimated 2,000 traditional furrows which tap water supplies from springs and rivers. Some of these have been improved in more modernised irrigation schemes, with the result that efficiency of water use ranges now from less than 15% to over 50%. Over 20 different crops are grown by small-holders in the basin, with most farmers growing a variety. Maize is the most ubiquitous crop, both in irrigated and non-irrigated areas. Coffee is grown by most households on Mount Kilimanjaro and Mount Meru. This is usually in association with bananas, grown by almost 90% of households in this area, and maize. Bananas are also grown by about a third of households in the lowlands. Tomatoes are grown in all areas, but tend to be more frequent in irrigated areas, particularly in the highland area. Beans are very commonly grown in the upper basin and highlands, but not in the lowlands.

While the highlands are too cool for rice production, it is a major crop of irrigated areas in the upper basin, and is planted to a small extent in the lowlands, in irrigation areas or in close proximity to flooding areas. Farmers in the highlands and upper basin that do not have access to irrigation concentrate their efforts on maize, beans and onions, as well as a variety of fruits and vegetables. Sugarcane is a very minor crop on smallholder farms, but grown throughout the basin. Cassava is only grown in the lowlands, as are peri-peri, paprika and fiwi. Okra is more commonly grown in the lowlands. Around the Pangani estuary, farmers concentrate on coconuts, betelnuts, cassava, sweet potato and pumpkin, as well as maize and bananas, but there is very little irrigation.

Survey data from a small sample of households throughout the basin suggests that income from crops is typically in the range of Tsh 350,000 – 600,000 per household per year. However, much higher incomes have been reported from traditional furrow systems in the upper basin, in some cases higher than that of improved irrigation schemes.

Nevertheless, it is easily demonstrated that irrigated areas produce higher incomes per ha than fields without irrigation in the upper basin. This was not necessarily the case in the Kirua swamp area, where similar incomes are obtained from crops grown within regularly-flooded areas to that from furrow irrigation areas nearby. The non-irrigated agriculture around Pangani estuary yielded similar incomes per ha to the rest of the lowland areas. Estimated average gross income per m3 of water used ranges from Tsh 100 – 1,400, depending on the area of the basin and the type of irrigation.

Livestock
Livestock are kept throughout the basin. In the highland and upper basin areas, households keep small numbers of cattle and goats and sometimes sheep. In the densely-populated highland and upper basin areas, most cattle are stall-fed ('zero-grazing') dairy cattle, but a few households in the upper basin have larger herds (up to 32), which are grazed. In the lowlands, cattle and goat herds are much bigger, and almost all associated with the Maasai community, who are also the only community keeping donkeys. Other tribes in this area keep very few livestock, mainly small number of goats. Very few households keep livestock close to the coast. Income per unit of water consumed ranged from Tsh 480 - 2,300, being highest in the highlands, but was also high for Maasai herds in the lowlands.

Table 1. Average value added per m3 water in different uses. These are rough estimates only*.

Type of use	Estimated water consumption	Estimated average value (Tsh per m3)
Domestic use	18 – 70 m3/head	1200 – 1500
Coffee estates	1000 m3/ha	723 – 6205
Sugar estates	12 – 17 000 m3/ha	32 - 101
Flower farms	18 250 m3/ha	3500 - 5300
Small scale irrigation		
Highland traditional furrow	3000 m3/ha	211
Upper basin traditional furrow	3000 m3/ha	475 – 574
Upper basin improved schemes	850 – 1195 m3/ha	574 – 1400
Lowland traditional furrow	3000 m3/ha	109
Livestock		
Highlands (dairy cattle)	36 m3/head	2263
Upper basin (dairy & beef cattle)	27 m3/head	860
Lowlands (beef cattle, goats)	18 m3/head, 2.5 m3/head	479 – 926
Aquatic ecosystems	?? m3/ha wetland	Still unknown
Hydro-electric power production	2.4 -19 m3/kWh	73 – 300(?)

*Estimates are based on a study conducted in Oct-Nov 2003, which entailed interviews with TANESCO, municipalities, estate managers, irrigation scheme representatives, and 203 households in 14 villages in four parts of the basin. For full details see Turpie et al. (2003).

A note on water values
It is important to note that the average values presented here are not values upon which water allocation decisions should be based. The average value of water in different productive activities is a problematic concept, because it is impossible to 'allocate' the net benefit of a production activity to any one of its inputs, such as water. The measure that is actually required is the net marginal value of water in different uses. This is the added value gained by adding an extra unit of water to any particular use. As more water is allocated to any particular use, the added value will diminish. This sort of value is determined by the construction of data-intensive production functions in which the change of output can be predicted for a change in water input, and should be the focus of future studies.

The Value of Water
Environmental Goods and Services
Water supply in the Pangani River Basin is crucial to the functioning of the basin's aquatic ecosystems. Apart from the intrinsic value of these ecosystems, they provide goods and services that contribute to the economic well-being of inhabitants of the basin. These include aquatic plants, such as reeds, sedges, mangroves, food and medicinal plants, and aquatic animals, including fish, crocodiles, hippos and water birds that can be harvested for household consumption or sale. The supply of all of these goods and services is affected by the quantity and quality of runoff in the catchment. Their value is determined by the degree of use and the sustainability of that use.

On average, households derive modest incomes from aquatic resources, increasing from a very small amount of income in the highlands to a fairly large amount in Pangani estuary. Fisheries are the major source of income from aquatic resources, but palms also make a substantial contribution. The value of plants such as reeds and sedges are small, but this belies the degree to which they are used. Their low value is due to their relative abundance. The value of mangroves is probably underestimated. Although income from aquatic resources is small, they are significant in the context of overall household income. The perception by households themselves is that aquatic resources contribute some 4 – 23% of household income (including subsistence values).

Linking the values of aquatic ecosystem goods and services to flow is more problematic, however. Calculation of the average value per m3 water would require relating the supply of these goods and services to the overall annual flows in different parts of the basin. This would not be a particularly useful measure, however, since the relationships between flow and the production of ecosystem goods and services is complex, and yet to be studied in the Pangani River Basin.

More importantly, as is true for all of the values reported in this study, the average values calculated are not as important as understanding the marginal value of water in different uses. For example, how will reed supply change if water allocation to the environment changes in a particular area? Such estimates can only be made in conjunction with a scientific study.

Table 2. Overall average value per household derived from harvesting of aquatic resources (including value added in processing), averaged across user and non-user households (Tsh per year)

	Highlands	**Upper basin**	**Kirua Swamp**	**Pangani estuary**
Food & medicinal plants	63	815	2 383	170
Reeds, sedges and grasses	2 120	2 433	2 852	0
Palms	0	4 269	4 434	86 721
Mangroves				7 890
Reptiles, mammals & birds		6	8	
Fisheries		392	33 883	693 012
Average total income per household	**2 183**	**7 915**	**43 560**	**787 793**

Hydropower Production

The Pangani River makes a substantial contribution to Tanzania's electricity supply. The country's power supply is mainly from hydropower, with three Hydro-electric power stations in the basin, at Nyumba ya Mungu, Hale and New Pangani Falls, contributing 17% of the country's capacity. The power output never reaches the installed capacity, however, due to shortages of water flow. Power production at Nyumba ya Mungu relies on storage of water in the dam during rainy seasons and then a relatively constant release of water through the turbines.

This regulation by the Nyumba ya Mungu dam also ensures a relatively even flow to the downstream power stations at Hale and New Pangani Falls. The latter are more modern and translate flow into power far more efficiently, with New Pangani Falls being 8 times more efficient than Nyumba ya Mungu in terms of output per unit of water. The average price obtained per unit of power is Tsh 73/kWh. However, the value of power generation in terms of its impact on national economic output would be far higher.

Incentives for Sustainable Water Resources Management
Influence of Sectoral policies on water supply

National policies have an impact on how water resources are used and managed. Policies which have negative impacts are those which directly or indirectly promote natural resource exploitation (e.g. catchment deforestation) or weaken control of catchment resource use. Some of these same policies can also have positive impacts, however, depending on how they are translated into action. For example, privatisation and trade-liberalisation can create opportunities for greater efficiency and environmental friendliness when they occur in conjunction with incentive measures such as marketing standards and tradable pollution permits (see table on the right).

Sectoral policies also have major implications for water resources in the Pangani River Basin. While the environmental sector policies such as forestry, wildlife, environment, fisheries, beekeeping and water generally promote sustainable practices that would enhance water supply, policies such as agriculture and minerals do not have sufficient emphasis on curbing environmental damage and in some instances inadvertently promote it.

The result of the existing policy and management background is that there is little incentive for landowners to conserve catchment areas important for water supply, for industries and households to curb pollution, or for anyone with access to water to use it sparingly.

Landowners in important catchment areas are not rewarded for conserving forests and soil, which would usually carry a cost to the landowner. There is little to effectively discourage polluting water supplies, since regulation is weak. Access to water itself is technically regulated, but enforcement of these regulations is weak. Not all users are required to pay for their water, and among those that are, there is a general culture of non-payment for water for a whole range of users including urban domestic use and irrigation use. Indeed, even the structures that regulate flow into irrigation canals are often modified by local users so that they can draw off greater flows. When water is free or effectively free, there is no incentive to use it efficiently or to invest in technology that improves efficiency. This is especially true where such improvements are costly. Crop choices may not be optimal if water resources are not seen as a scarce input. The open access nature of water created by a weak system of control not only promotes over-utilisation but exacerbates conflicts as upstream users will take as much as they can, thereby depriving the downstream users of the valuable source.

Table 3. Macro-economic policies that can have negative or positive effects on sustainability of water use (depending on context)

Policy	**Negative**	**Positive**
Civil service and public admin reforms	✓	
Market liberalisation	✓	
Financial sector reforms	✓	
Reducing government expenditure	✓	
Deregulation of forex controls	✓	
Privatisation	✓	✓
Trade liberalisation	✓	✓
Fiscal reforms	✓	✓
Export promotion and globalisation	✓	✓

Integrating economic instruments into sectoral policies

The new water policy proposes that all water users will be charged, and charges will include instruments such as pollution charges. Provided this can be enforced, appropriate fees and penalties should create incentives for conserving water resources and abating pollution. The issue of catchment degradation will also need to be addressed.

Economic instruments that should be employed as incentive mechanisms include:

- *Water pricing* – encouraging efficient use and generating revenues for catchment management
- *Tradable water rights* – to promote efficiency of water use
- *Pollution charges* – to internalise the external costs of pollution and generate revenues for rehabilitation
- *Tradable pollution permits* - to internalise the external costs of pollution and create the incentive for abatement
- *Subsidies and taxes* – to penalise damaging activities and reward conservation efforts
- *Watershed conservation payments* – paid by the PBWO to the catchment managers (public and private) in return for certain management actions that enhance water supply services.

There is a wide array of economic instruments which can be integrated into sectoral policies and contribute to sustainable management of water resources. Some of the sectoral policies have already recognised the need to include these instruments in their Acts while other sectors are still contemplating this.

The survey and consultations with stakeholders conducted by Mkenda and Ngaga (2003b) showed that there are good prospects for introducing economic instruments for environmental management in Tanzania. The use of user charges, fees, taxes, royalties and fines is widespread in the country, even if they were not necessarily put in place for regulating behaviour with respect to the environment and water resources, but for revenue generation. The fact that such instruments are in place makes it easier to adapt them in various policies as economic instruments for sustainable water resources.

Financing Integrated River Basin Management

A drastic improvement in the management of the basin's water resources will require improved funding. As it is, the Pangani Basin Water Office cannot meet their obligations adequately with their existing funding. This stems from (a) inadequate provision from central government (via the Ministry of Water and Livestock Development) and (b) inadequate recovery of water user fees. The result of this is that the PBWO has inadequate resources for planning, enforcement and monitoring, let alone for setting in place a system for the optimal allocation of water resources.

In 2003-2004, most of the PBWO's finances came from user fees (65.9%), including a TANESCO royalty (30%) which is divided between established water basins. In 2005-2006, the TANESCO royalty will become as less significant component of the PBWO budget as it will be shared amongst all nine river basins.

There is an enormous capacity to increase the revenues from user fees due to the large degree of non-payment, and due to the fact that most users are currently not charged for water use at all. Improved collection should be the priority, but this will require ensuring the equity of the water user fee system as well as improving the enforcement capacity of the PBWO.

The way forward
The increasing scarcity of water resources in the Pangani River Basin calls for strategic water resources management that will ensure the sustainability of water supply and the goods and services supplied by aquatic environments, as well as the efficient and equitable use of these resources. Sustaining water supplies for the numerous users in the basin will depend on reducing losses due to catchment degradation and wastage due to inefficient practices. The former will need to be addressed by creating incentives for catchment managers to maintain catchment forest areas, preferably through a system of 'payments for ecosystem services' which involves payment by those that benefit from the service, via the PBWO, to catchment managers. The price increases required for this will also serve as a demand management tool that encourages more efficient use of the water that is allocated to various uses.

Before water is allocated among different user sectors, it will be necessary to allocate sufficient water to aquatic ecosystems to maintain ecosystem functioning and the values derived from them. This can be achieved with the help of an 'instream flow assessment' which takes both ecological and socio-economic factors into account.

It is possible that ecological requirements can be met by better water management without compromising the amount of water that can be utilised. The allocation of remaining flows needs to be done in such a way as to achieve maximum economic benefits from water within the constraints of certain equity and sustainability considerations. This will best be achieved through more rigorous study of the economic benefits of water in alternative uses in different parts of the catchment, together with the use of a multi-criteria decision tool that can take other goals into consideration.

A project intervention in Pangani Basin will begin to explore some of these relationships by collecting information on the economic, environmental and social costs and benefits of various water allocation scenarios.

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